Hunting Hurricanes with GPS

and a few other things, besides

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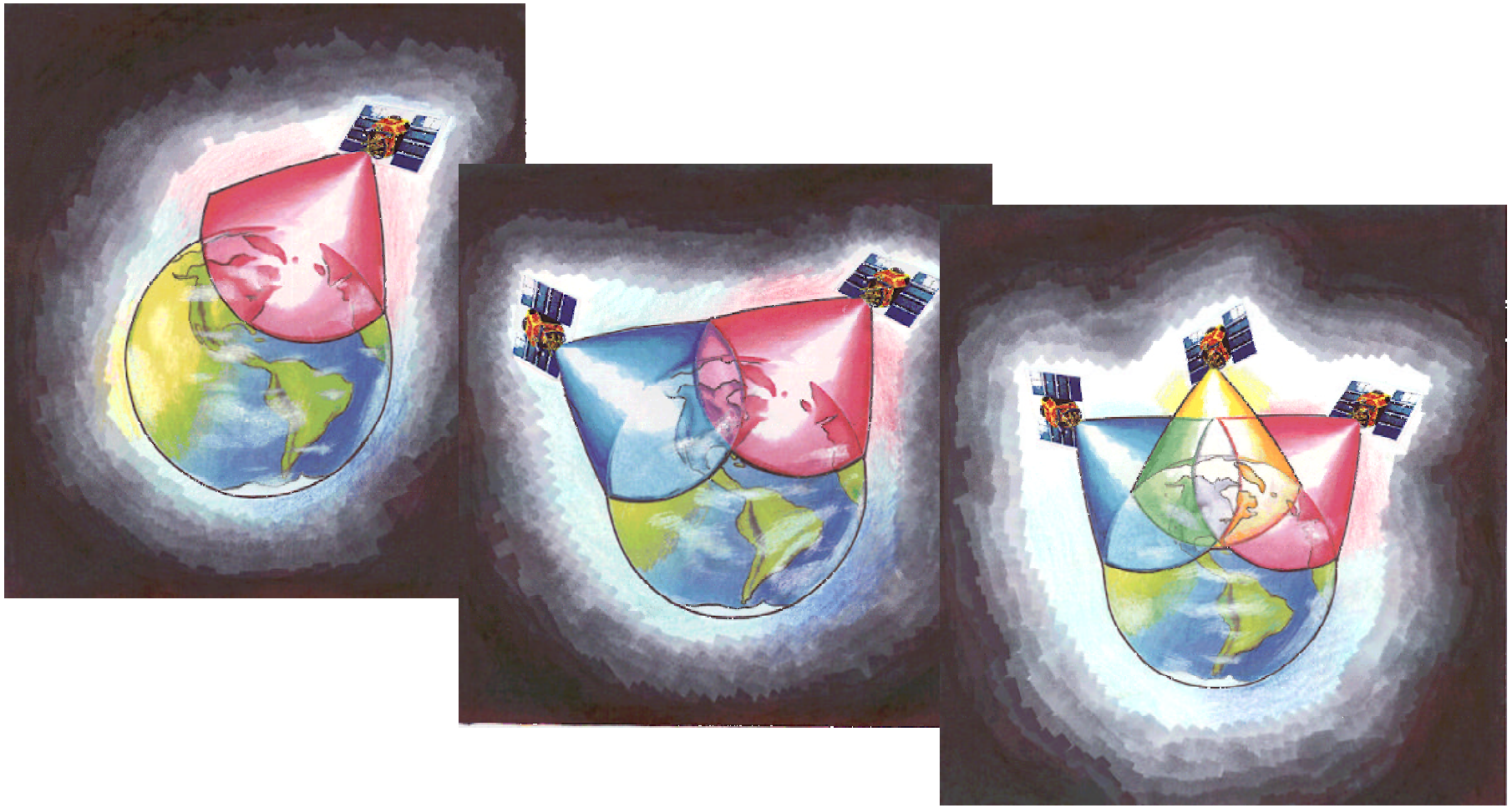
NASA-Langley Research Center
February 12, 2002

What is GPS *

* The Global Positioning System

How does GPS work?



GPS Surface Reflections
Background

- In 1994 French researchers reported an accidental acquisition of GPS over rough, Atlantic waters, much to their surprise.

- Signal was strong enough to be tracked and an erroneous position fix generated. “Work-arounds” developed and the work was dropped.

- Two of us here at Langley recognized the significance of the French results, and began a study of the remote sensing applications of the water reflection.

GPS Surface Reflections
Fundamental Principles

- The reflection of GPS from water is very high
- For a calm body of water the surface behaves almost the same as a mirror to the GPS signal.
- The reflected signal can be almost as strong as the direct signal and nearly indistinguishable from it.
- An aircraft with a bottom antenna would sense this reflected signal as a normal GPS signal, an error called *multipath.*

GPS Surface Reflections

Fundamental Principles

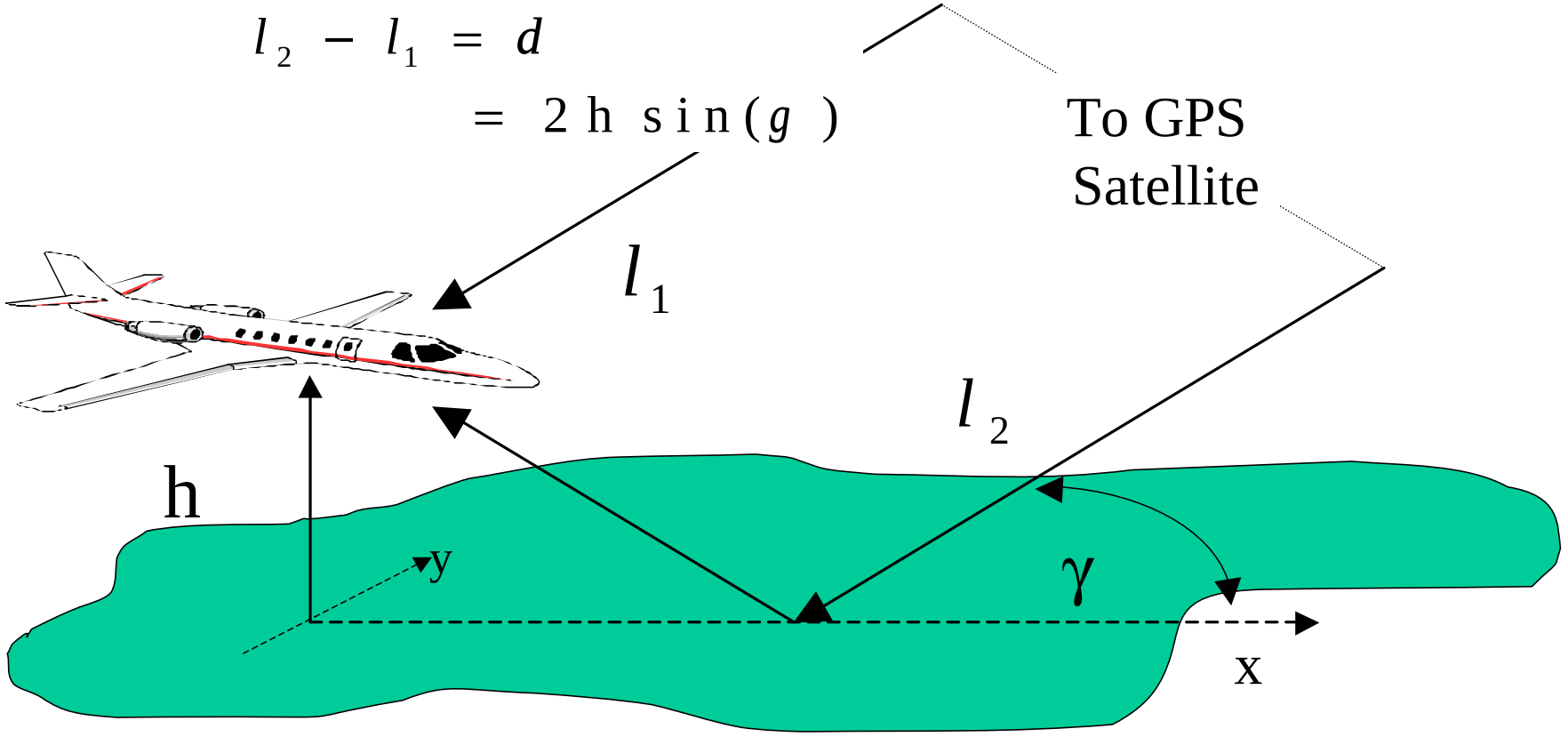
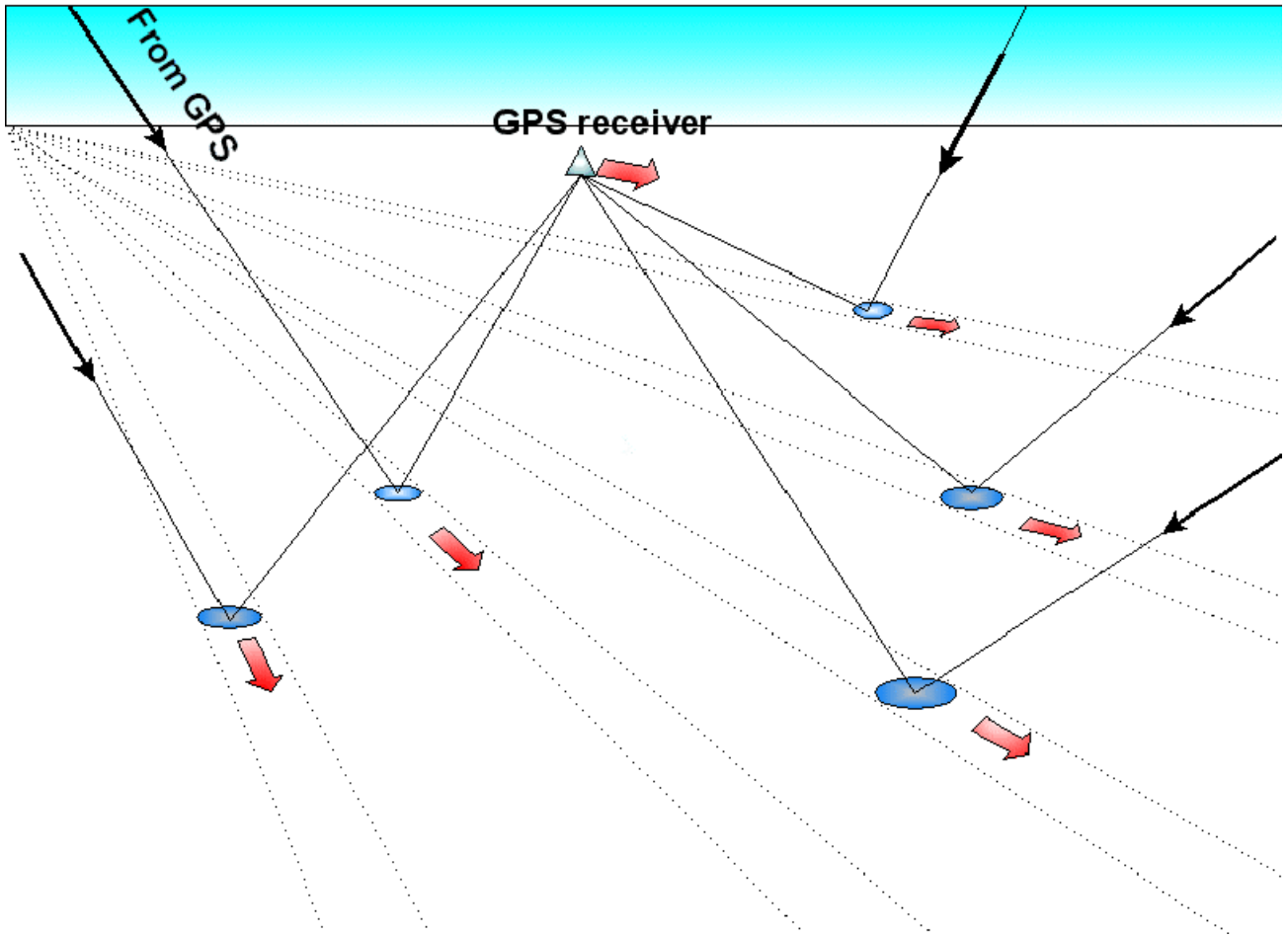


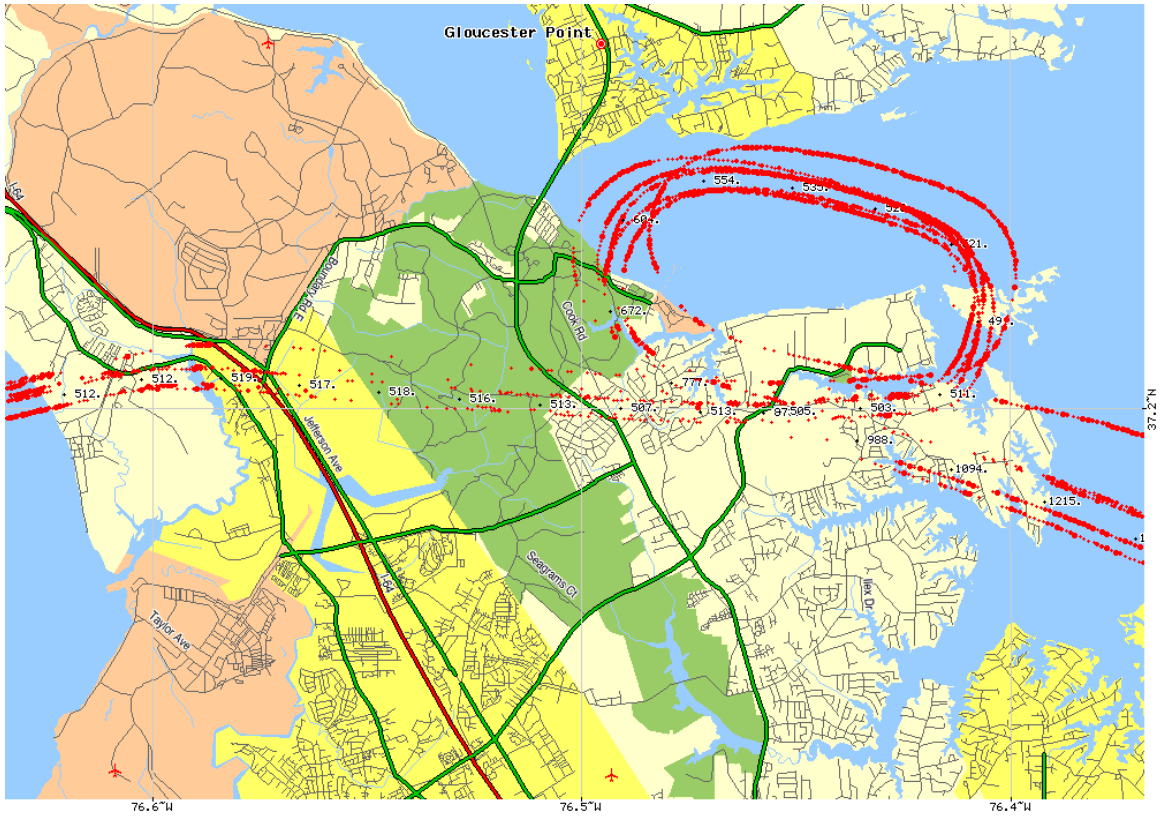
Figure 1 Illustration of geometry describing reflected GPS signals in an aeronautical application. The GPS satellites are assumed to provide uniform signals in the form of a plane wave.

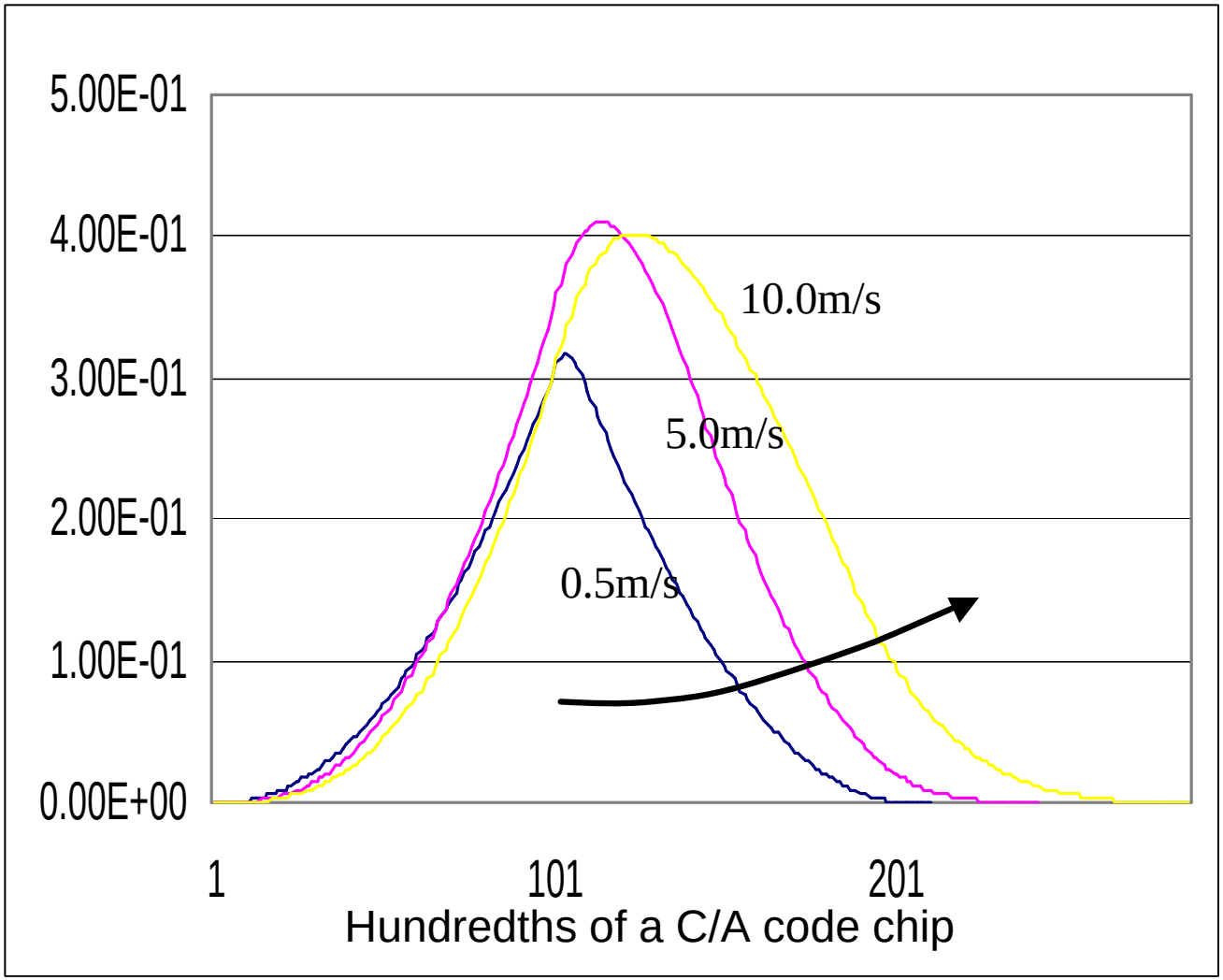
GPS Surface Sampling

The World at L-Band



An Example of GPS Sensitivity to Water

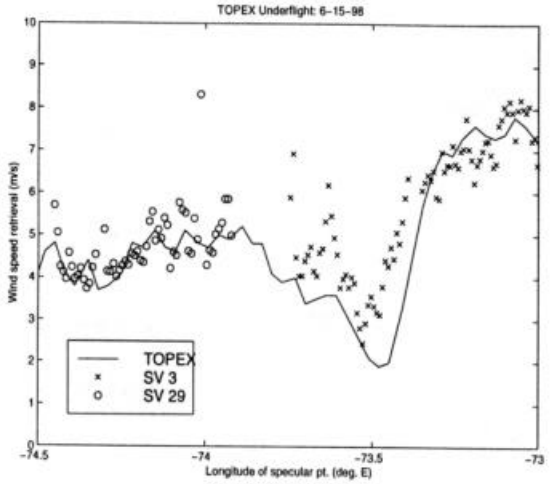


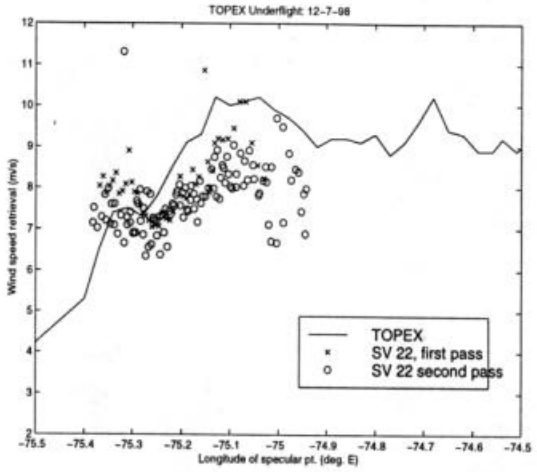


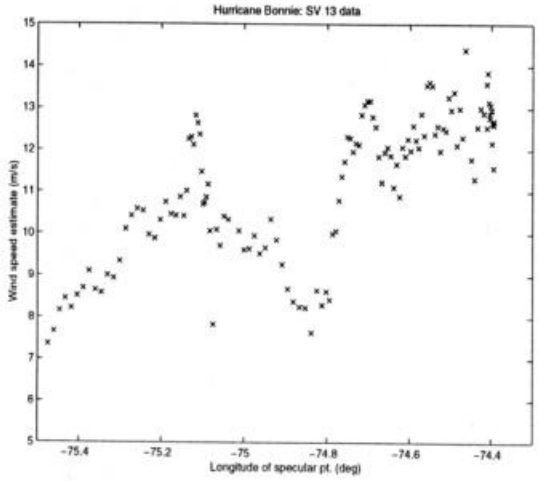
Effect of increasing wind speed on internal GPS correlation function. Widening is a direct indicator of surface roughness.

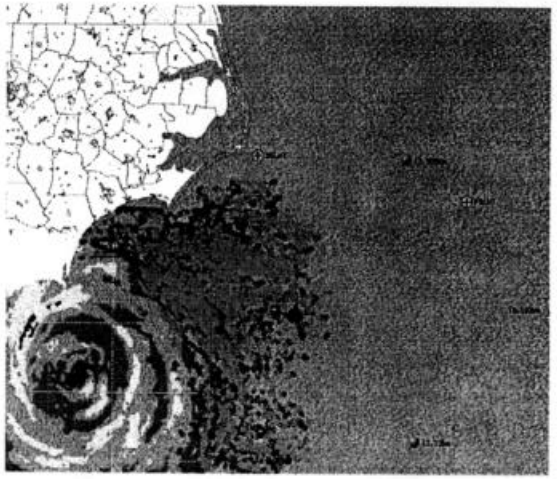
Illustration of Retrievals

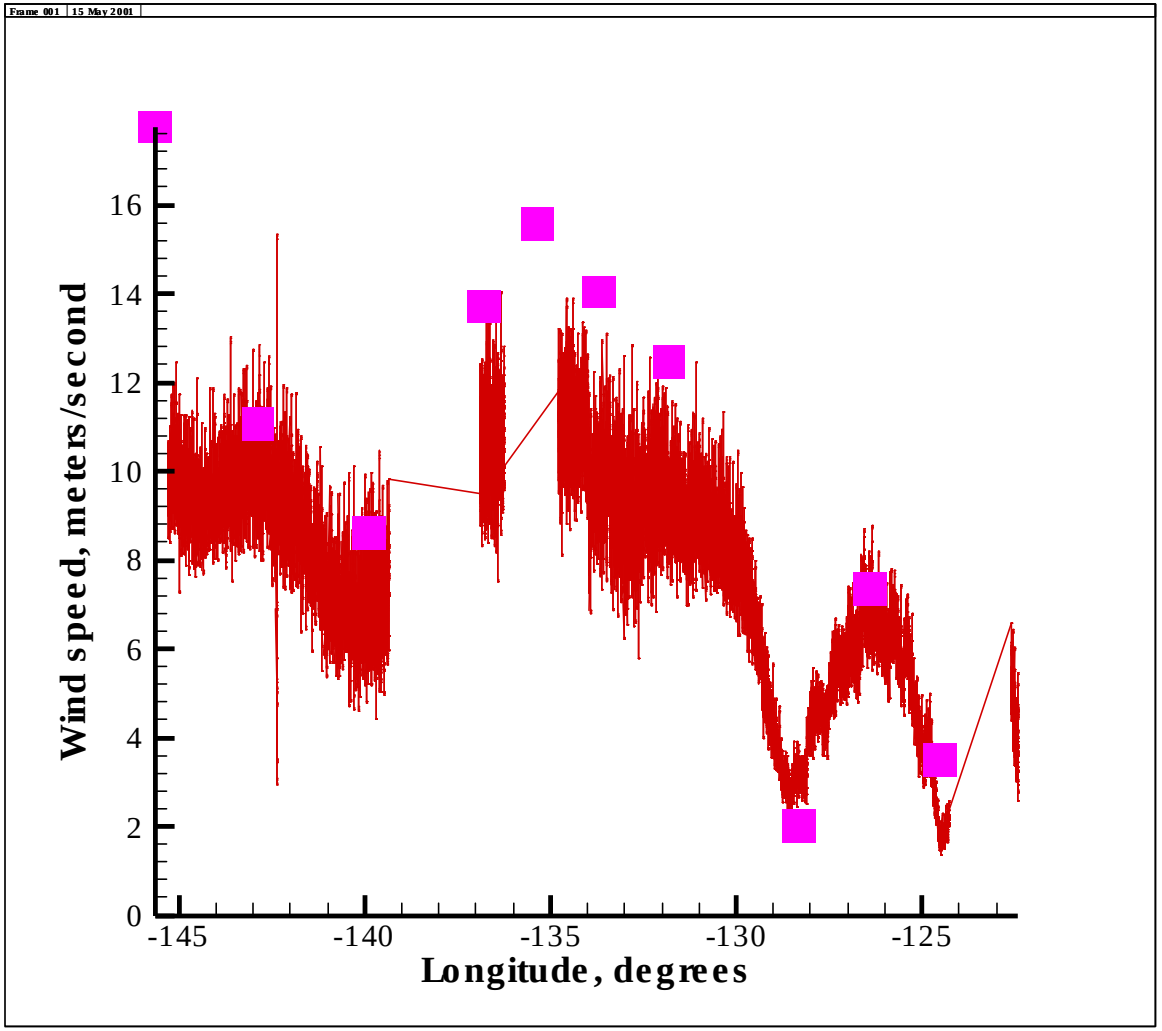
TOPEX Underpass and Outer bands of Bonnie ‘98









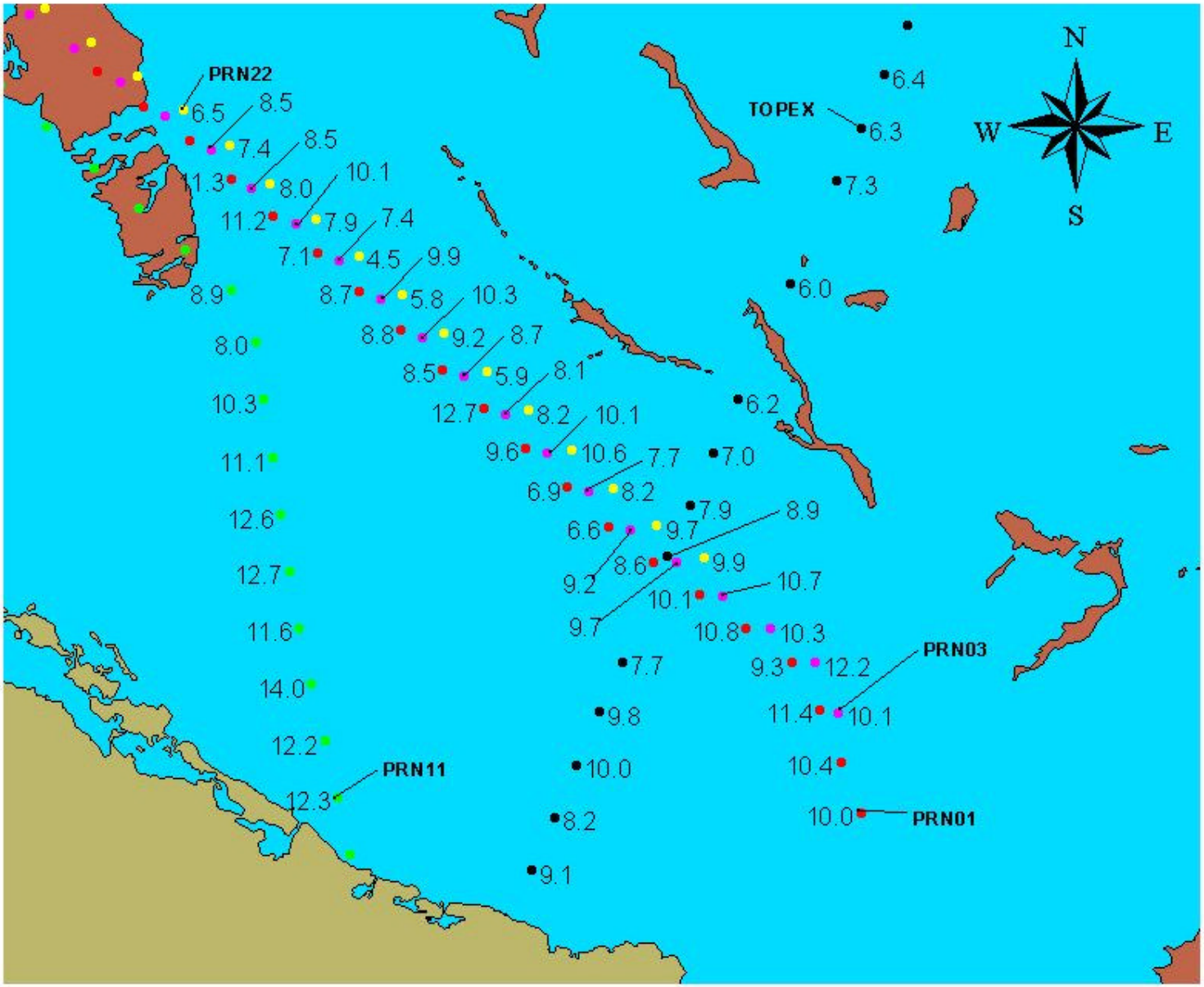

Frame 001
15 May 2001
Wind speed, meters/second
0
2
4
6
8
10
12
14
16
-145
-140
-135
-130
-125
Longitude, degrees

Lockheed WP-3D Orion

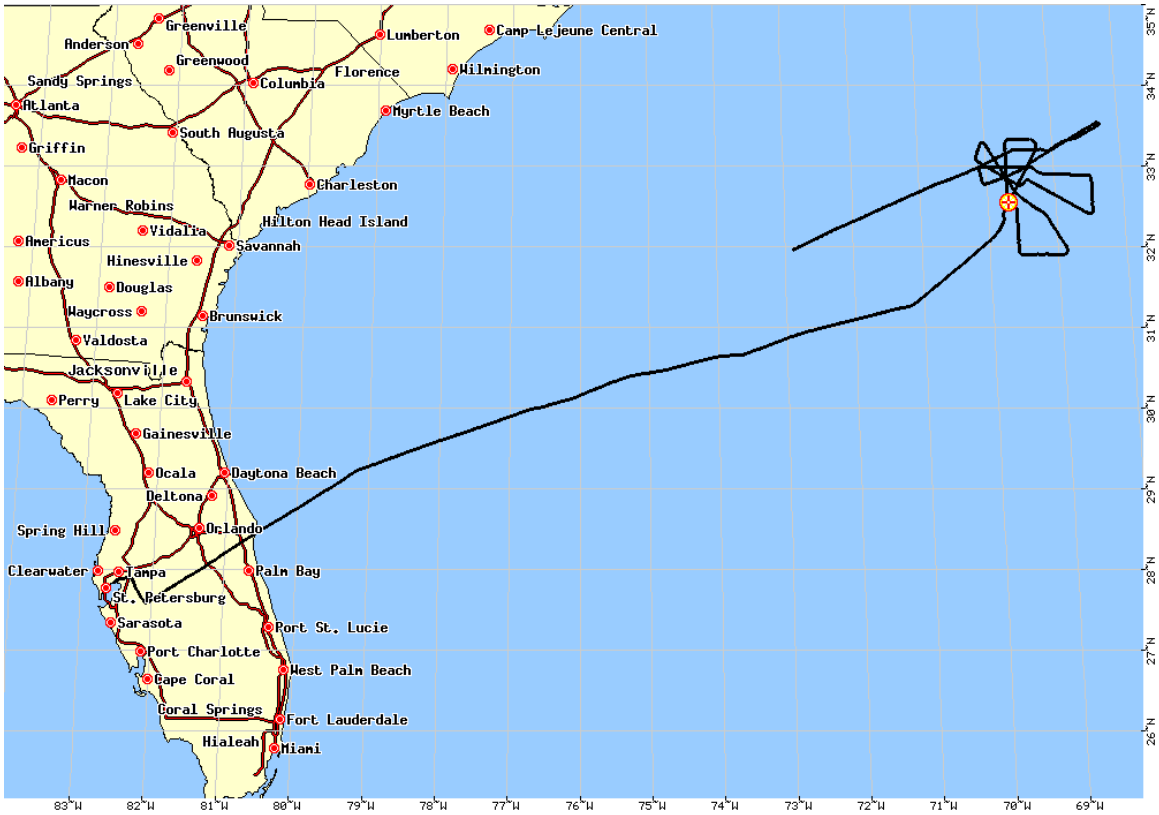
The renowned NOAA WP-3D Orions, participate in a wide variety of national and international meteorological, oceanographic and environmental research programs in addition to their widely known use in hurricane research and reconnaissance. These versatile turboprop aircraft are equipped with an unprecedented variety of scientific instrumentation, radars and recording systems for both in-situ and remote sensing measurements of the atmosphere, the earth and its environment.

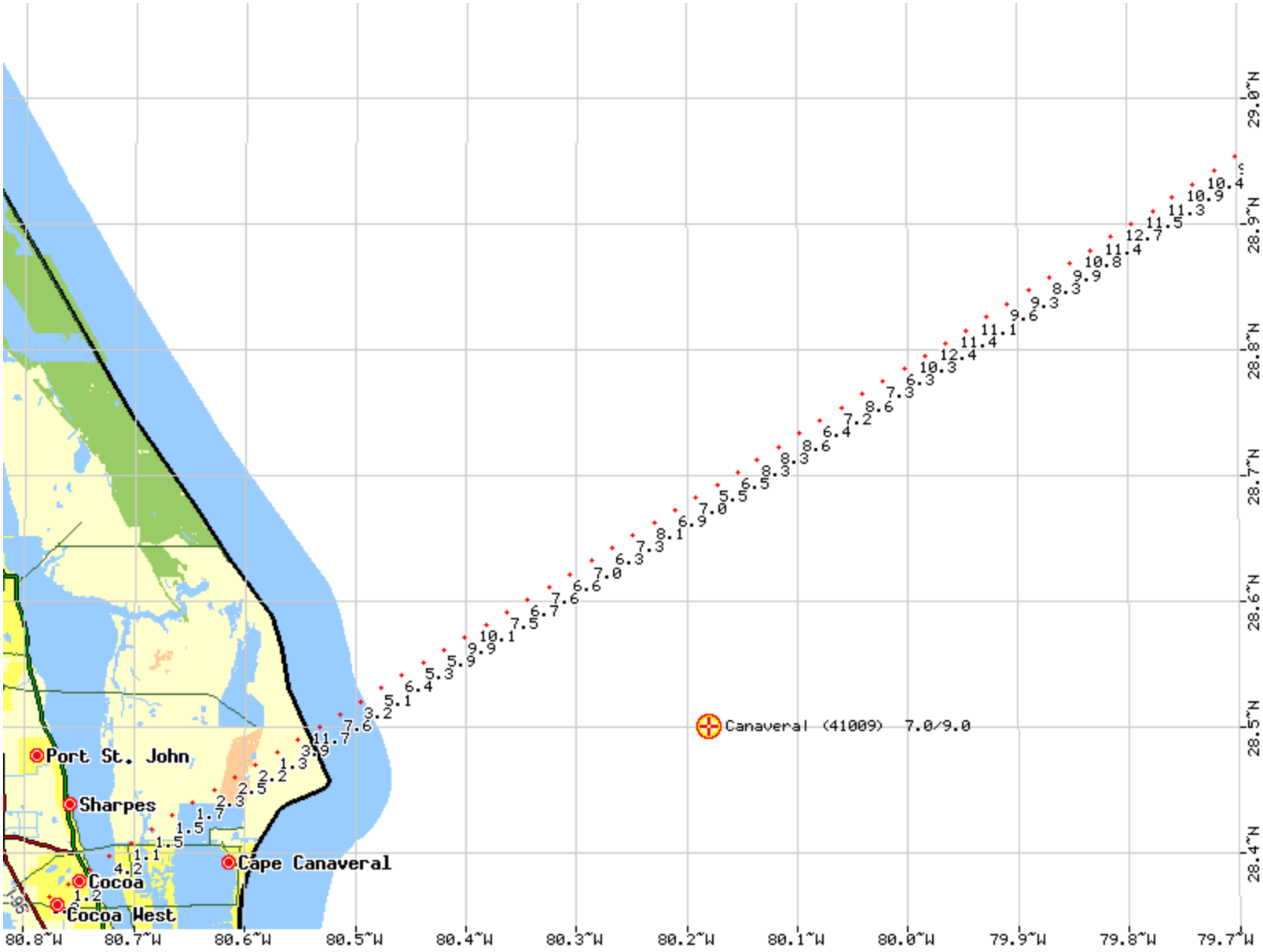
GPS Surface Reflection - Wind Speed
Hurricane Debby (082300)

GPS Surface Reflection - Wind Speed
Hurricane Debby (082300)

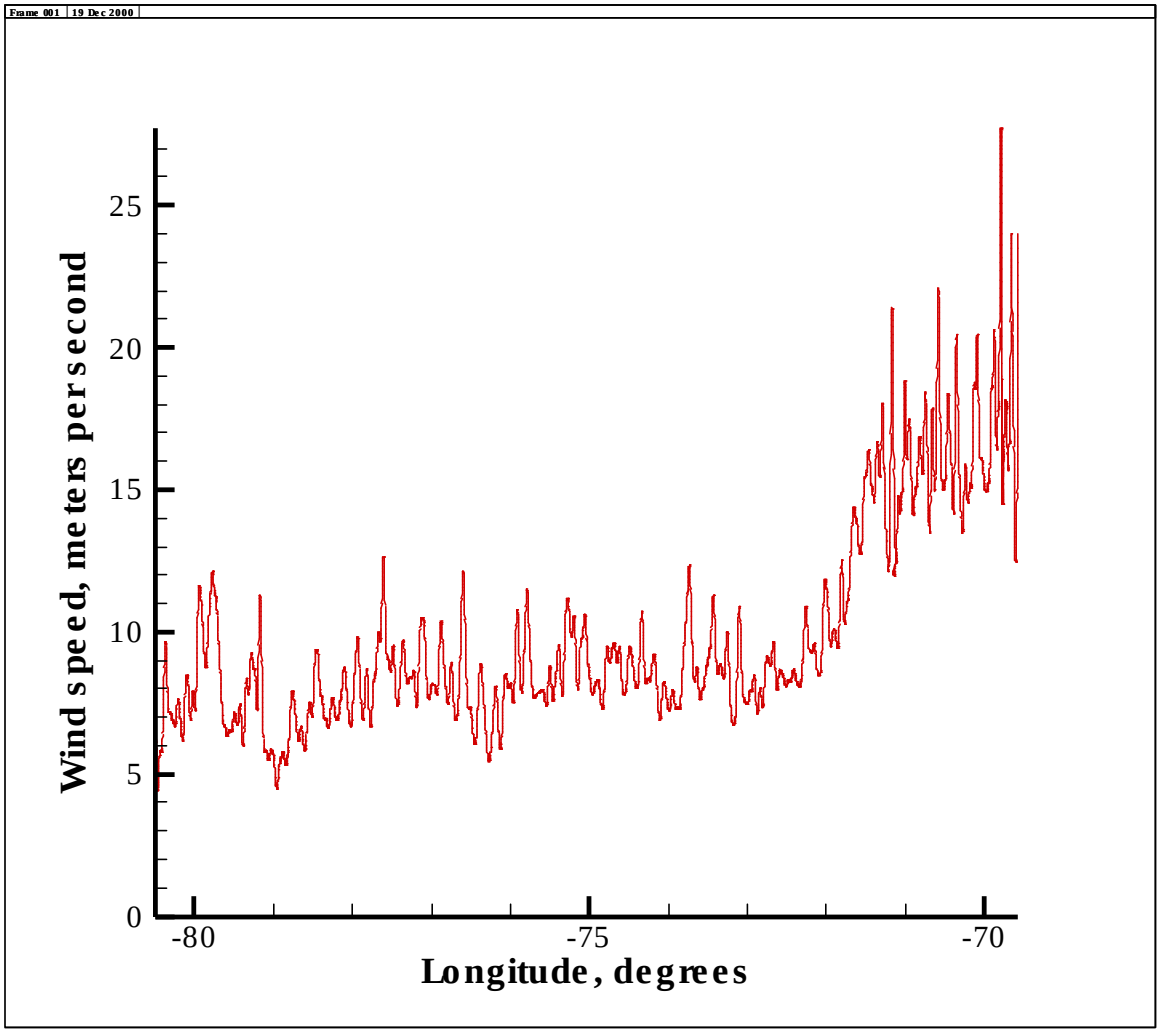


Hurricane Michael

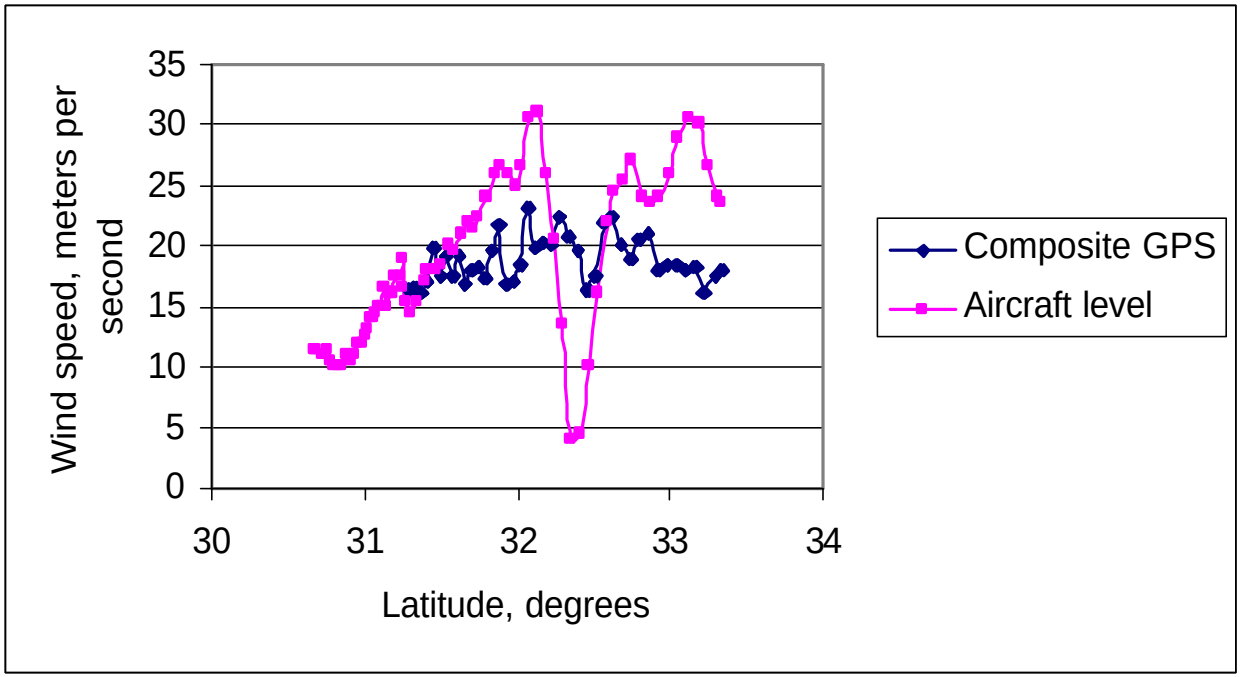


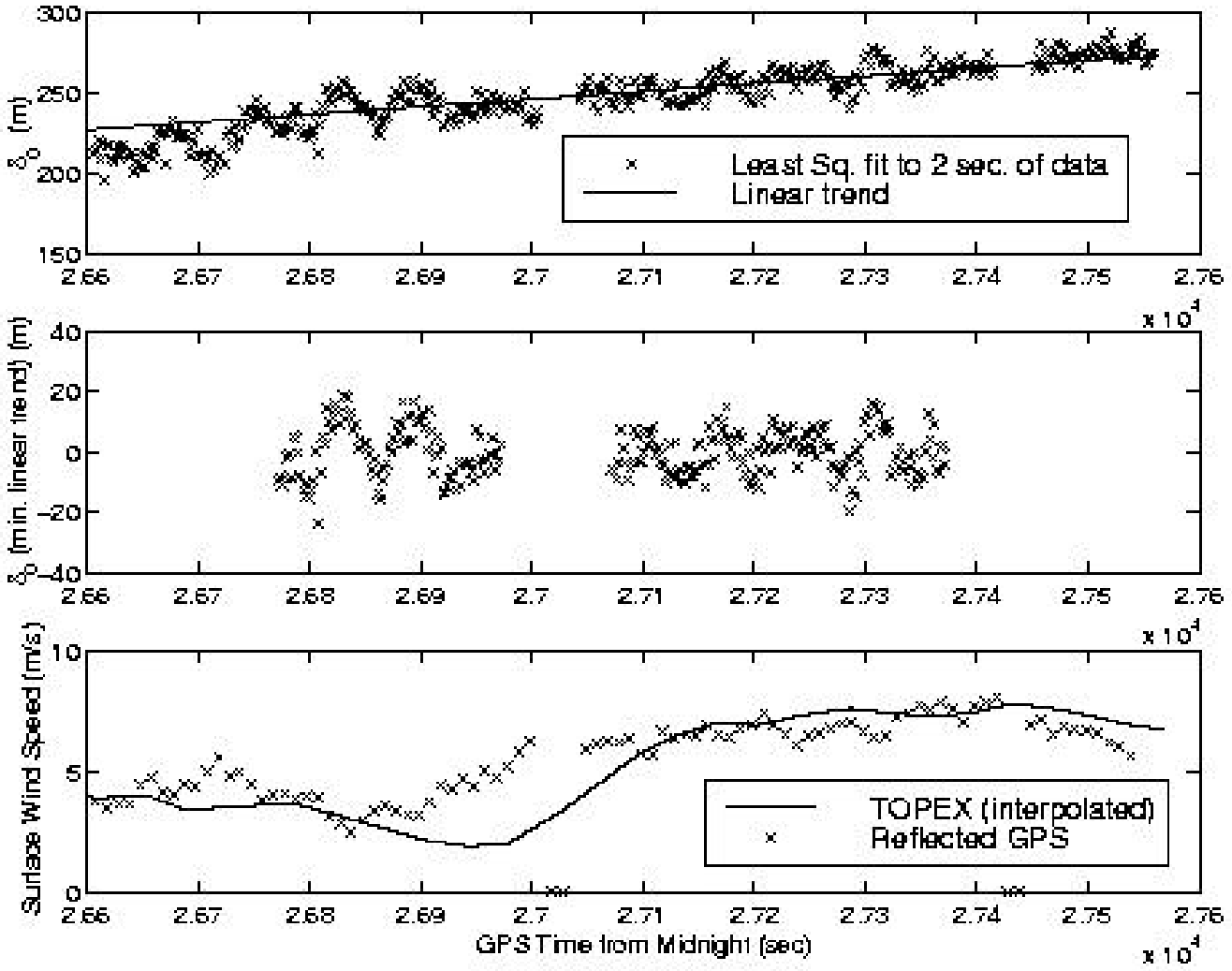

Port St. John
Sharpes
Cocoa
Cocoa West
Cape Canaveral
Canaveral (41009) 7.0/9.0
80.8°W
80.7°W
80.6°W
80.5°W
80.4°W
80.3°W
80.2°W
80.1°W
80.0°W
79.9°W
79.8°W
79.7°W
29.0°N
28.9°N
28.8°N
28.7°N
28.6°N
28.5°N
28.4°N

The Flight into Michael

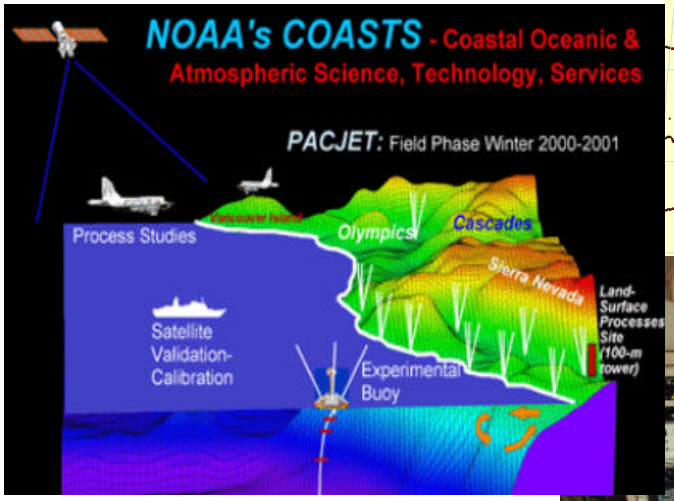


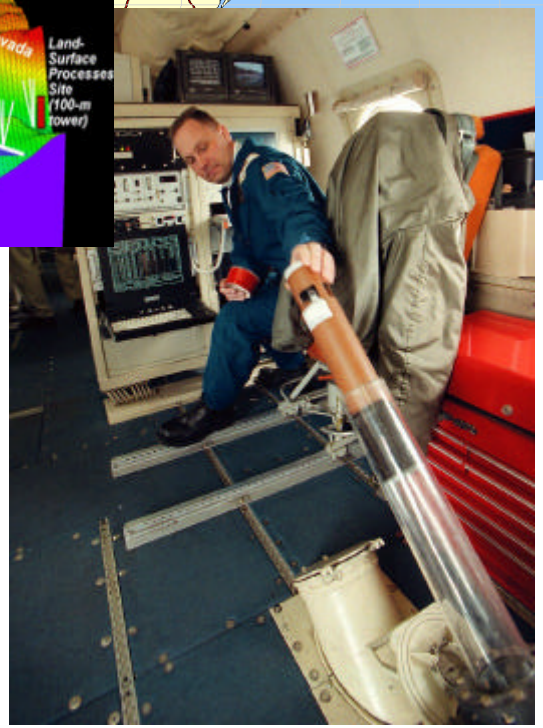
GPS data from eye of Hurricane Michael

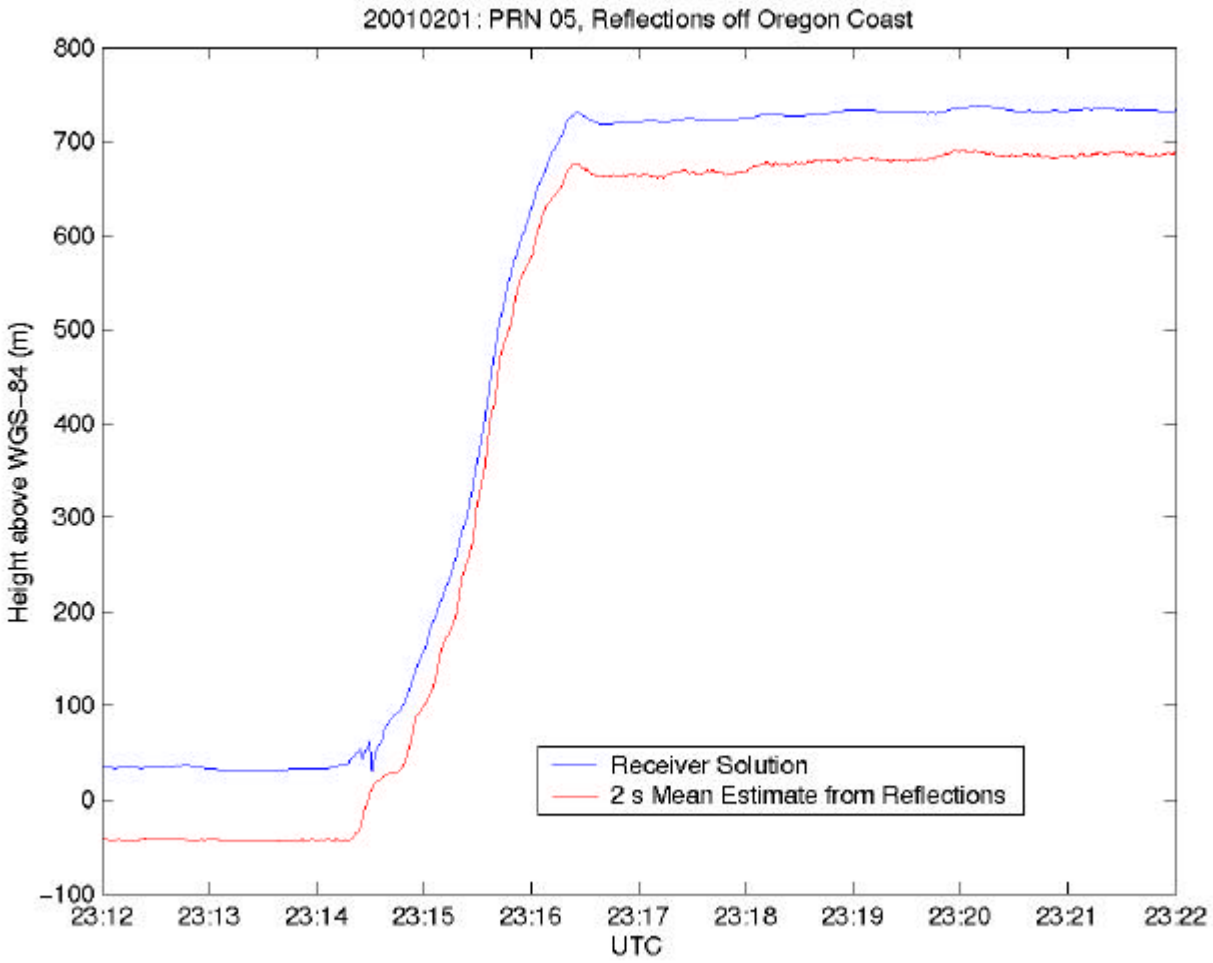


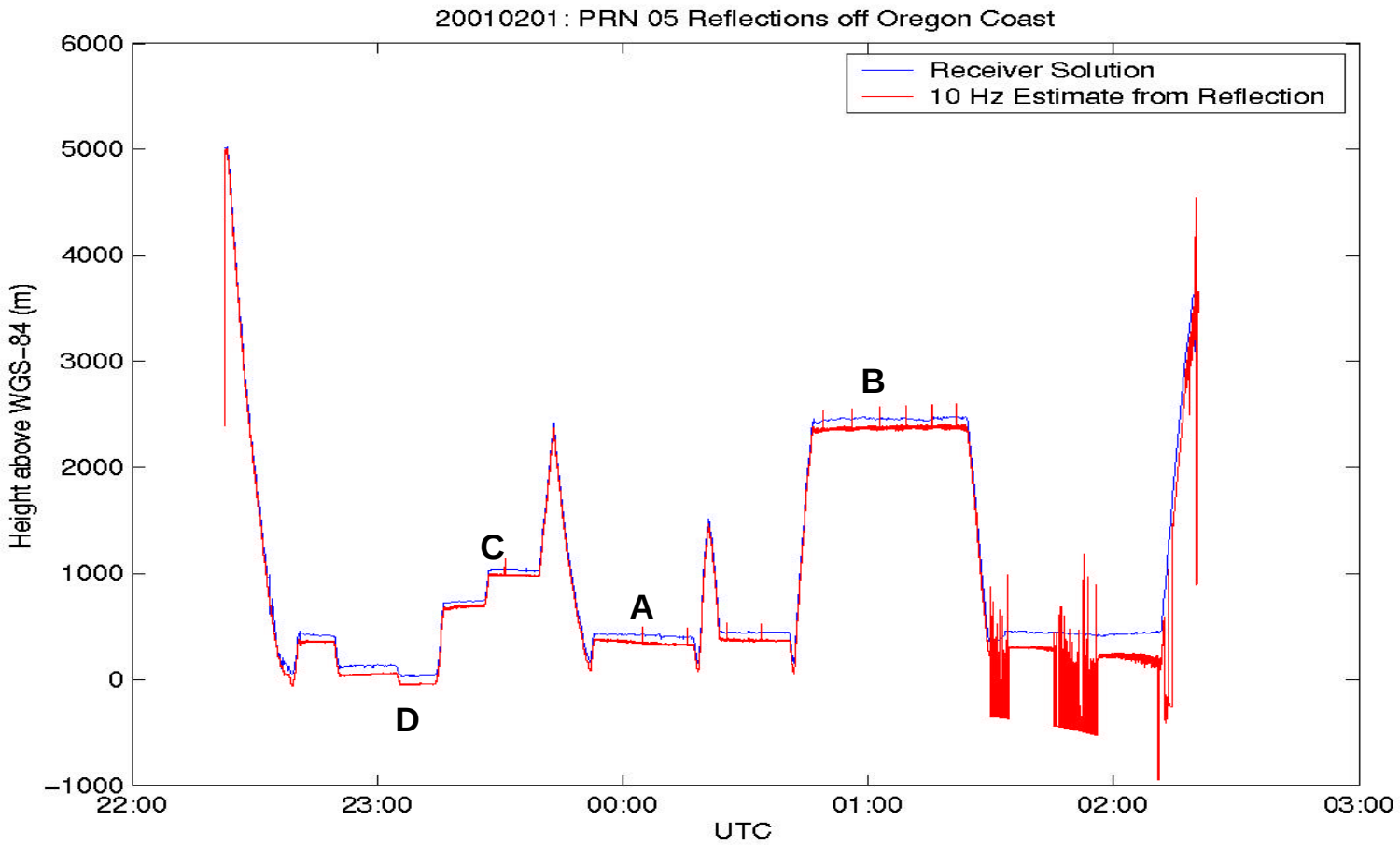

Least Sq. fit to 2 sec. of data
Linear trend
δρ (m)
δρ (min. linear trend) (m)
Surface Wind Speed (m/s)
TOPEX (interpolated)
Reflected GPS
GPS Time from Midnight (sec)
x 10^4

PACJET Mission off West Coast

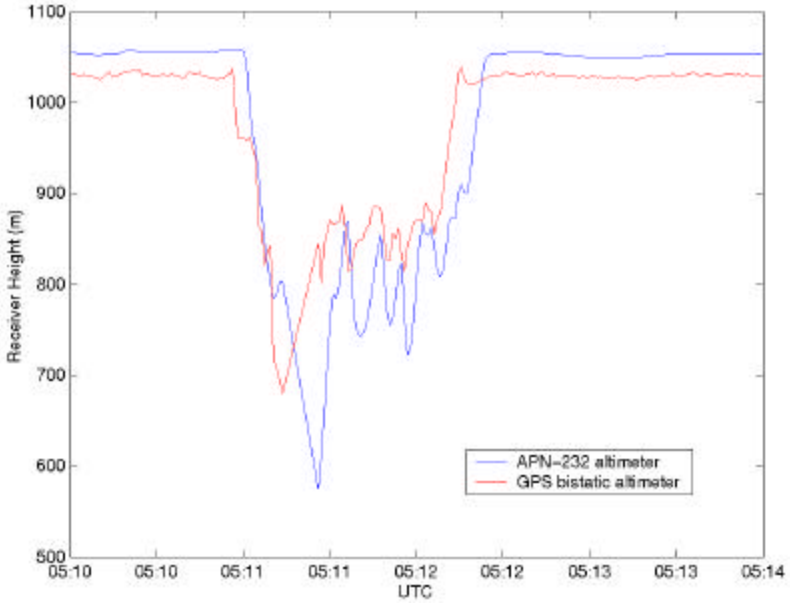





20010201 : PRN 05, Reflections off Oregon Coast
Height above WGS−84 (m)
800
700
600
500
400
300
200
100
0
−100
23:12
23:13
23:14
23:15
23:16
23:17
23:18
23:19
23:20
23:21
23:22
UTC
Receiver Solution
2 s Mean Estimate from Reflections


20010201: PRN 05 Reflections off Oregon Coast
Receiver Solution
10 Hz Estimate from Reflection
Height above WGS–84 (m)
6000
5000
4000
3000
2000
1000
0
−1000
22:00
23:00
00:00
01:00
02:00
03:00
UTC
A
B
C
D

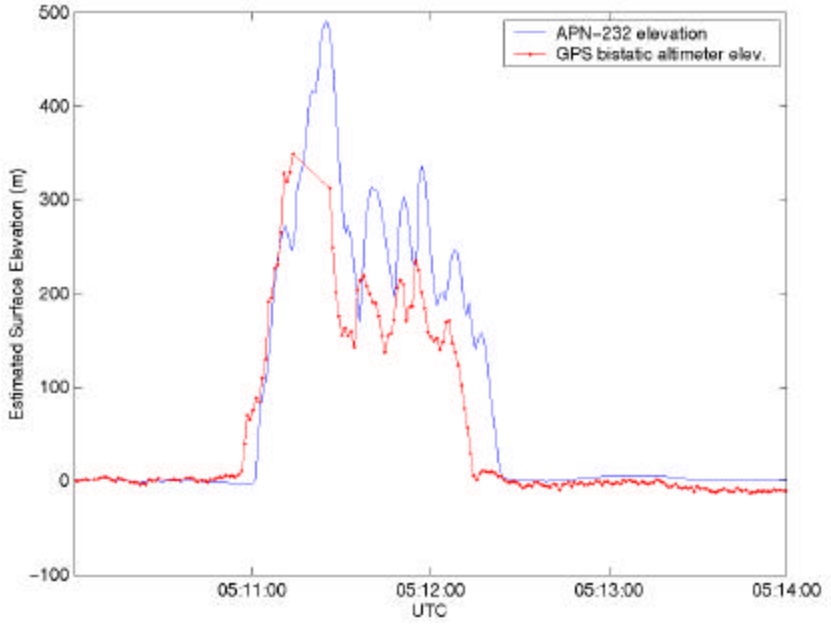
2001/02/12: Catalina Island



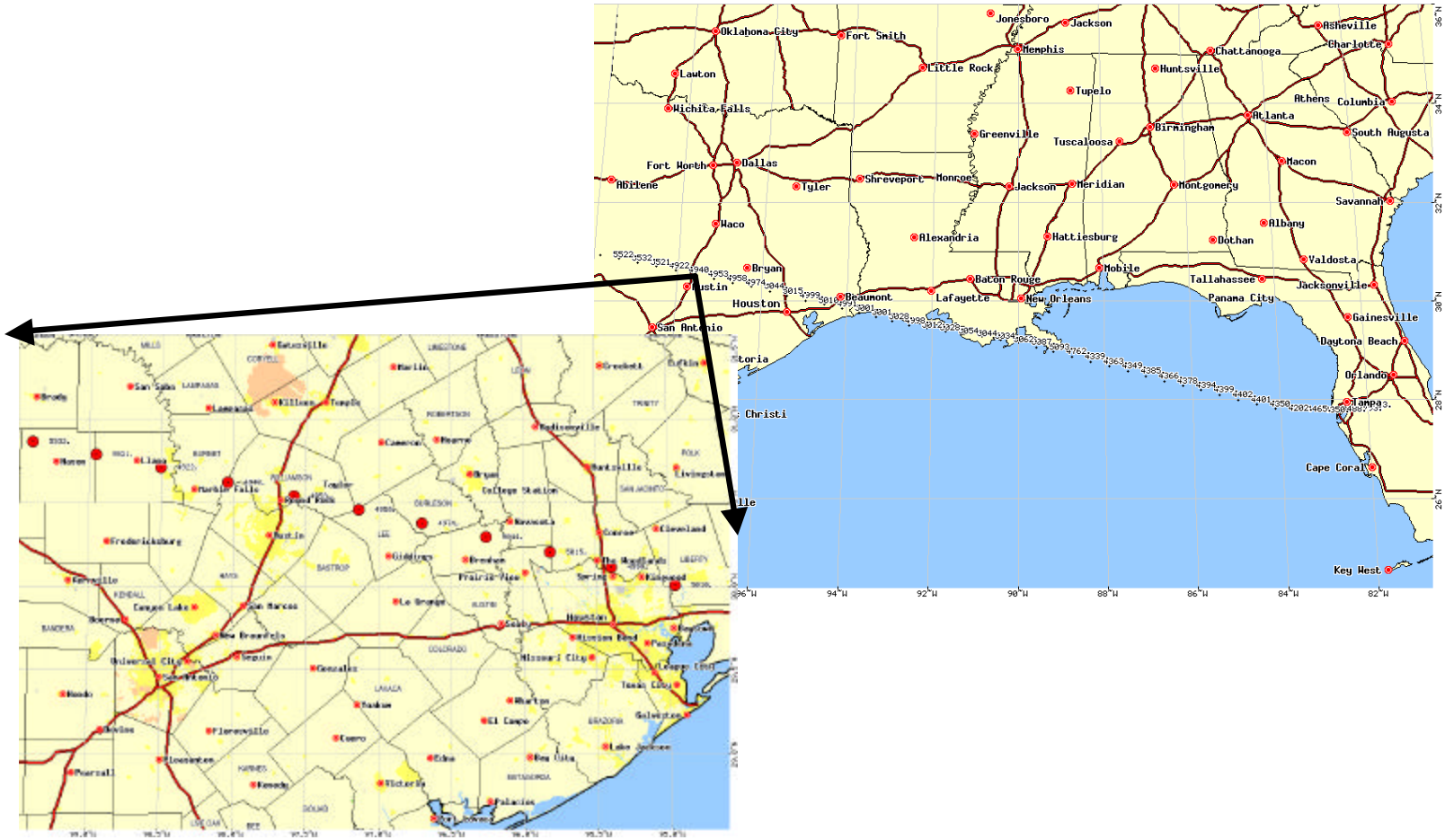
Height above surface

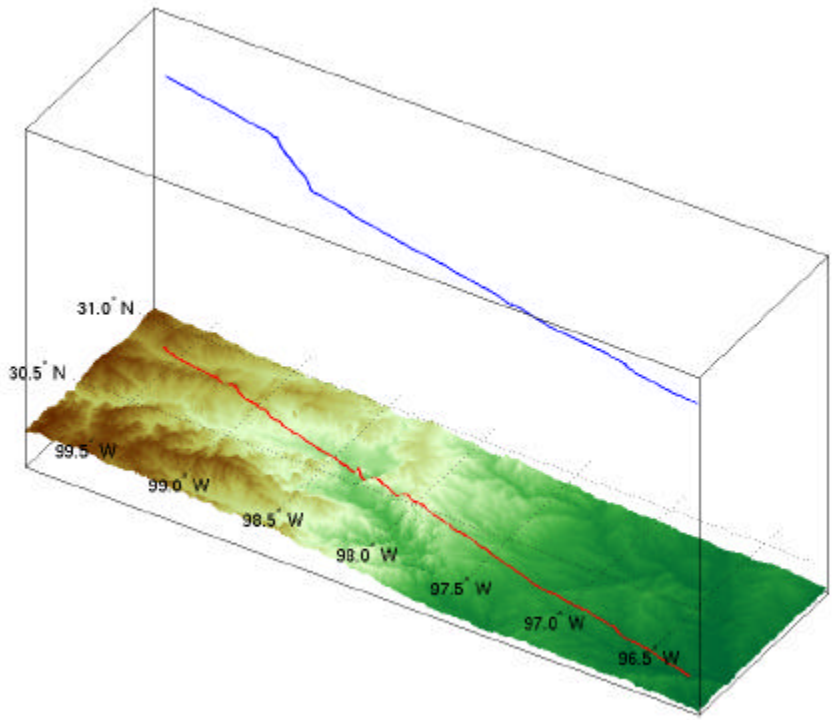
Offset due to specular/nadir point location difference

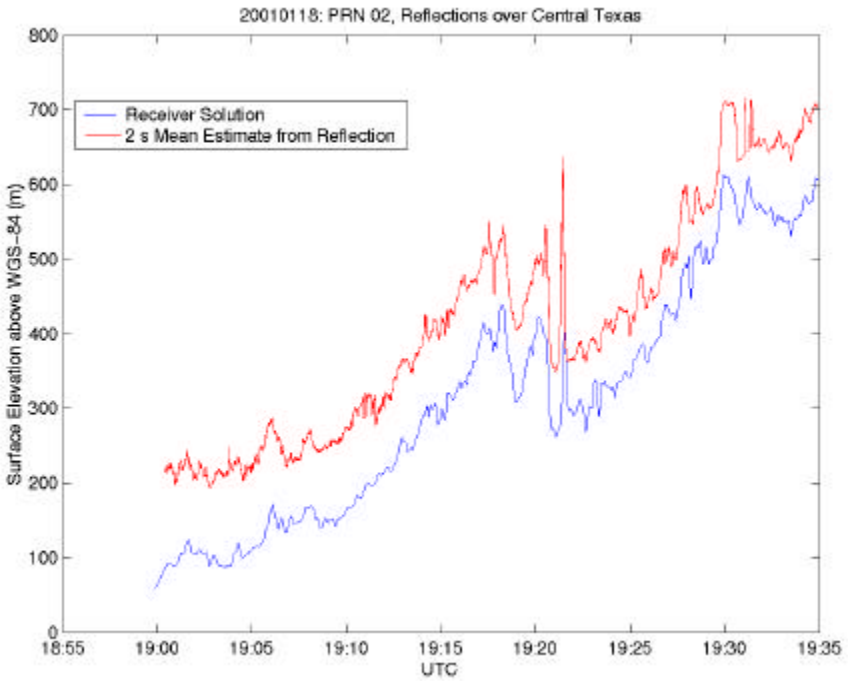
Height inverted for surface elevation estimate

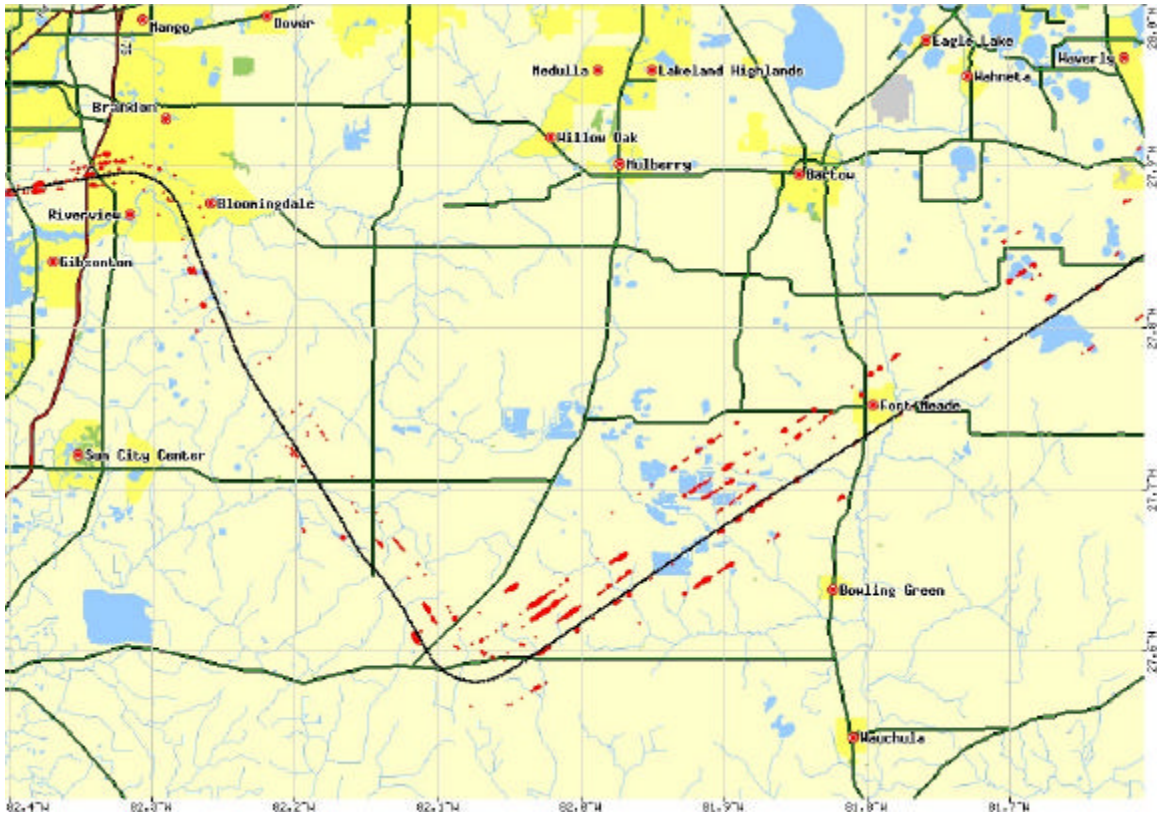


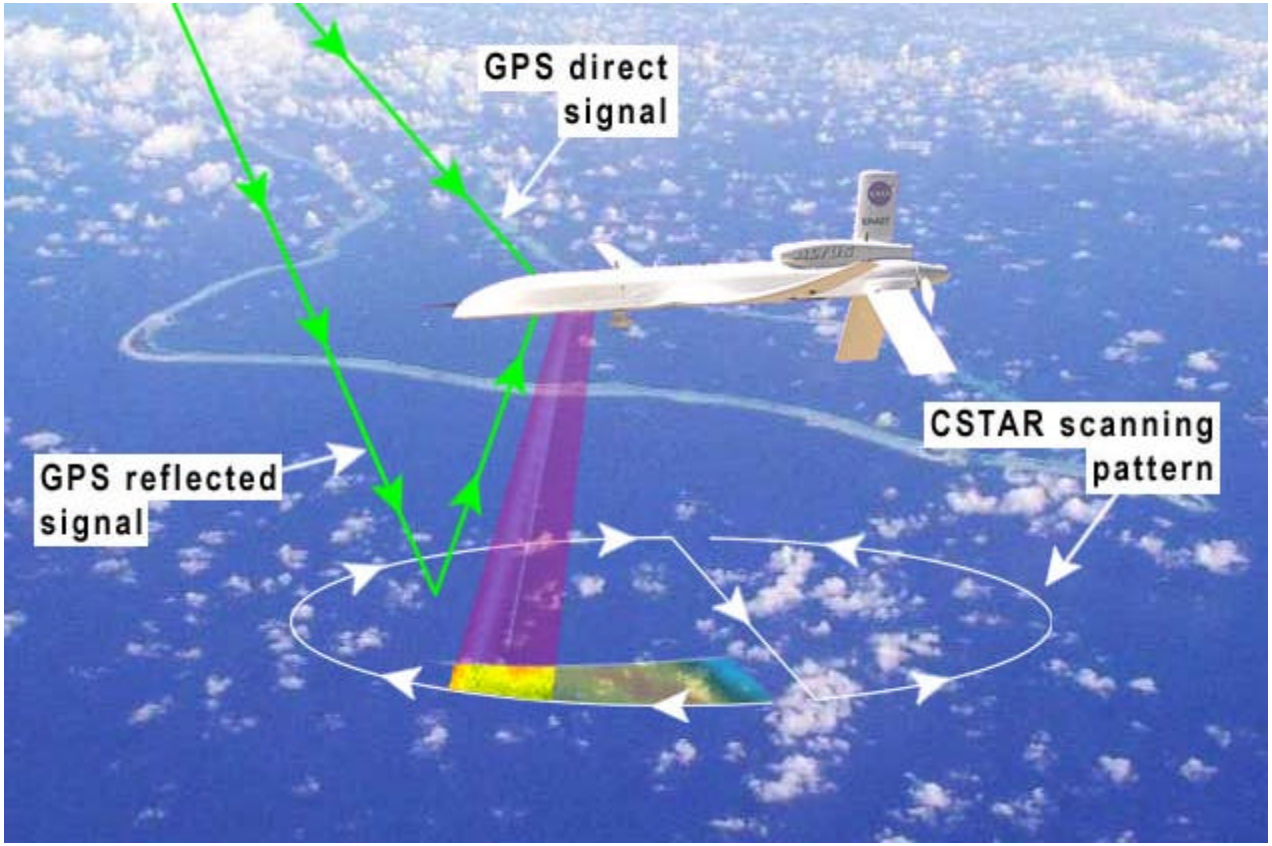
From University of Colorado ION paper, Masters, Axelrad, Katzberg,etc.


Jonesboro
Jackson
Asheville
Oklahoma City
Fort Smith
Memphis
Charlotte
Chattanooga
Little Rock
Huntsville
Lawton
Tupelo
Wichita Falls
Athens
Columbia
Atlanta
Birmingham
Greenville
South Augusta
Tuscaloosa
Fort Worth
Dallas
Macon
Abilene
Tyler
Shreveport
Monroe
Jackson
Meridian
Montgomery
Savannah
Waco
Albany
Alexandria
Hattiesburg
Dothan
Valdosta
Bryan
Mobile
Baton Rouge
Tallahassee
Austin
Beaumont
Lafayette
New Orleans
Panama City
Jacksonville
Houston
Gainesville
San Antonio
Daytona Beach
Orlando
Christi
Tampa
Cape Coral
Key West
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
38°N
32°N
26°N


31.0° N
30.5° N
99.5° W
99.0° W
98.5° W
98.0° W
97.5° W
97.0° W
96.5° W


20010118: PRN 02, Reflections over Central Texas
Receiver Solution
2 s Mean Estimate from Reflection
Surface Elevation above WGS−84 (m)
0
100
200
300
400
500
600
700
800
18:55
19:00
19:05
19:10
19:15
19:20
19:25
19:30
19:35
UTC


Mango
Dover
Medulla
Lakeland Highlands
Eagle Lake
Haverly
Mahmet
Brandon
Willow Oak
Mulberry
Bartow
Riverview
Bloomingdale
Gibsonton
Fort Meade
Sun City Center
Bowling Green
Wauchula


GPS direct signal
GPS reflected signal
CSTAR scanning pattern

GPS Surface Reflections

Conclusions

- The GPS signal reflected from ***land*** as well as water surfaces has been shown to be capable of use as an altimeter.
- The accuracy attainable from such an application can be on the order of a few meters or better.
- The measurements provided are positive indications and do not appear susceptible to false readings.
- The modifications to light aircraft and GPS receivers to add this capability are minor.